Supporting Information for "Estimating bioturbation from replicated small-sample radiocarbon ages"

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Additional Supporting Information (Files uploaded separately)

1. Captions for Dataset S1

Introduction

Text S1 and Figure S1 contain extended results of the simulation study to examine the bias in the estimation of age-heterogeneity due to the non-linear relationship between $F^{14}C$ and age. In this supporting material we examine the behaviour of the bias over a wide parameter space that exceeds the range of age-heterogeneities that would be encountered in real samples - but that allows the full shape of the function to be characterised.

Dataset S1 contains R code and the radiocarbon age measurements to replicate the analyses in this study. These data have been submitted to the Pangaea archive (DOI PENDING) but are additionally supplied here in a form that will work directly with the supplied R code.

Text S1.

Here we examine the examine the behaviour of the bias in age-heterogeneity estimates, due to the non-linear relationship between $F^{14}C$ and age, over a wide parameter space that exceeds the range of age-heterogeneities that would be encountered in real samples.

Our bias simulation study indicates that, expressed as a proportion of the true age-heterogeneity, estimated age-heterogeneity decreases non-linearly with the true age-heterogeneity. This proportion tends towards a value of $\frac{1}{\sqrt{n_f}}$ at the limit of infinite age-heterogeneity, i.e. an infinitely low sedimentation rate (Figure S1). The vertical line in Figure S1 indicates an age-heterogeneity of 10 kyr, which corresponds to a bioturbation depth of 10 cm with a sedimentation rate of 1 cm kyr^{-1}. In most practical cases, samples that are being radiocarbon dated would fall to the left of this line, as cores with sedimentation rates of 1 cm kyr^{-1} can only be radiocarbon dated down to a depth of about 50 cm, as material that is deeper than this will be beyond the age limit for reliable radiocarbon dating. Therefore the maximum bias we are likely to observe would be a factor of approximately 1/2.

Data Set S1. R code and the radiocarbon age measurements required replicate the analyses in this study. These data have been submitted to the Pangaea archive (DOI pending) but are additionally supplied here in a form that will work directly with the supplied R code.

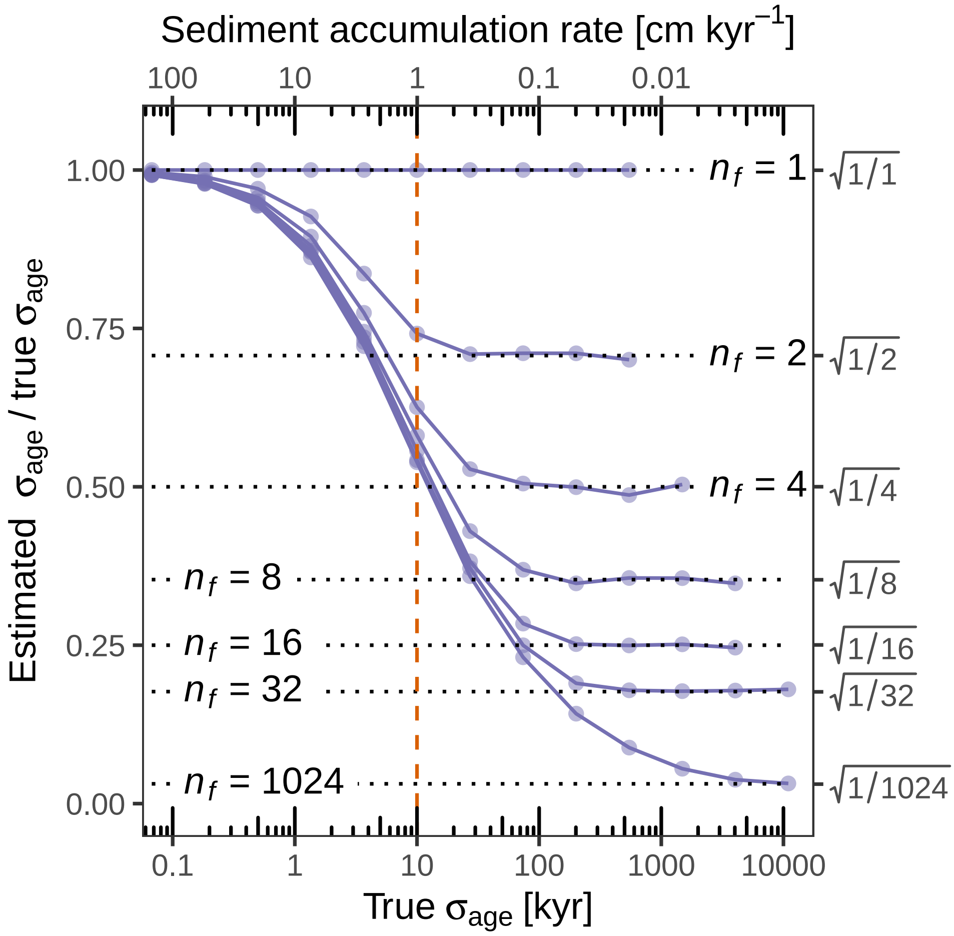

Figure S1. Simulation of the bias in the estimation of age-heterogeneity due to the exponential relationship between $F^{14}C$ and age, expressed as a proportion of the true value. The blue lines show the bias for samples with different numbers of individual foraminifera per radiocarbon date. As the true age-variance increases (as L increases or s decreases), the estimate becomes a smaller proportion of the true value and tends towards the square root of the inverse of the number of individuals per sample. The true σ_{age} values correspond to a core with bioturbation depth of 10 cm and sedimentation rates shown in the upper horizontal axis. The dashed vertical orange line indicates σ_{age} for a core with a 10 cm bioturbation depth and sedimentation rate of 1 cm kyr^{-1}.

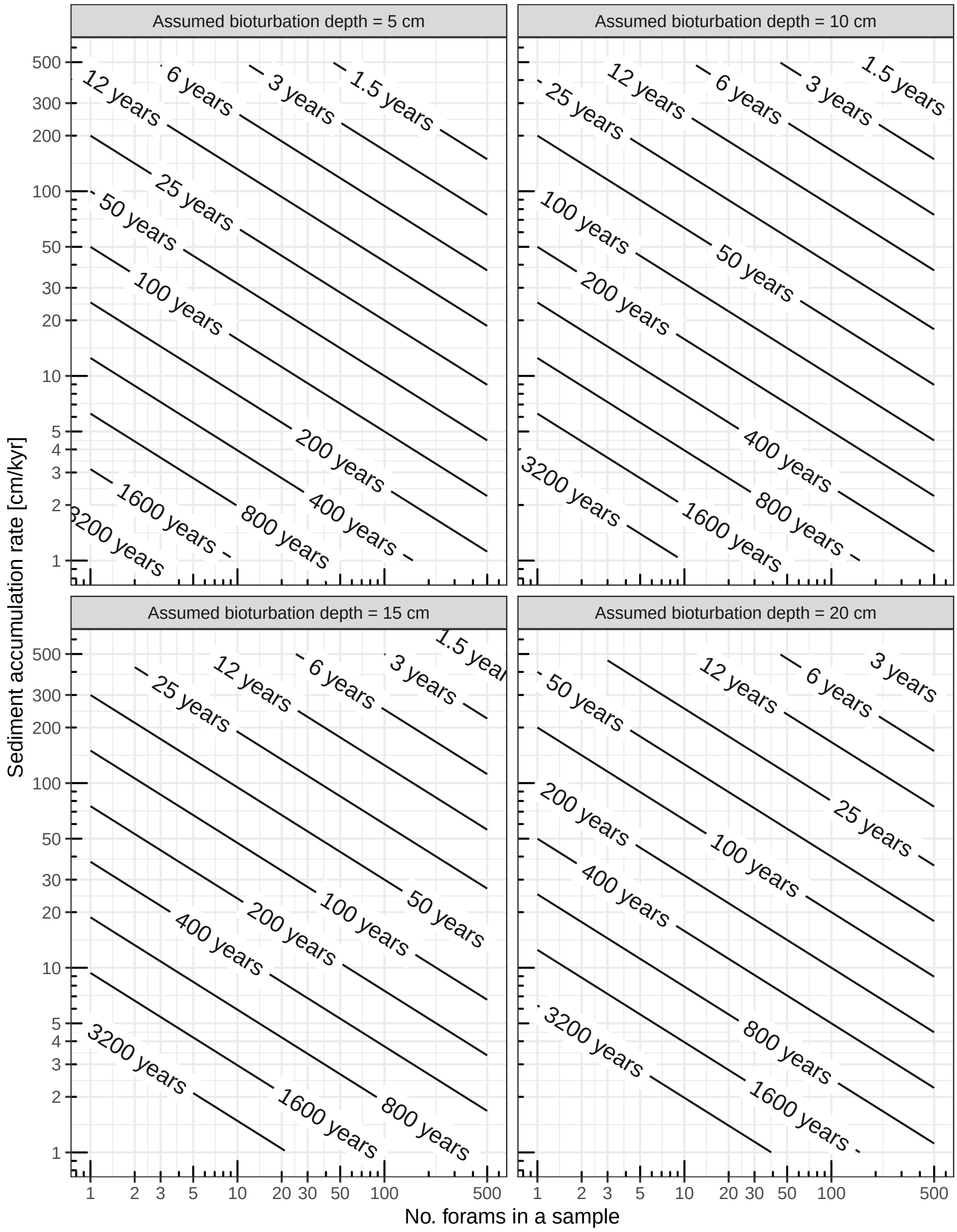

Figure S2. Additional reference charts to obtain estimates of the age-uncertainty σ_{age} for a sample measured on a given number of foraminifera, from the sedimentation rate of the core s, and assuming bioturbation depths L of 5, 10, 15 and 20 cm. Or alternatively, estimates of the number of foraminifera per sample needed to reduce σ_{age} below a given level.

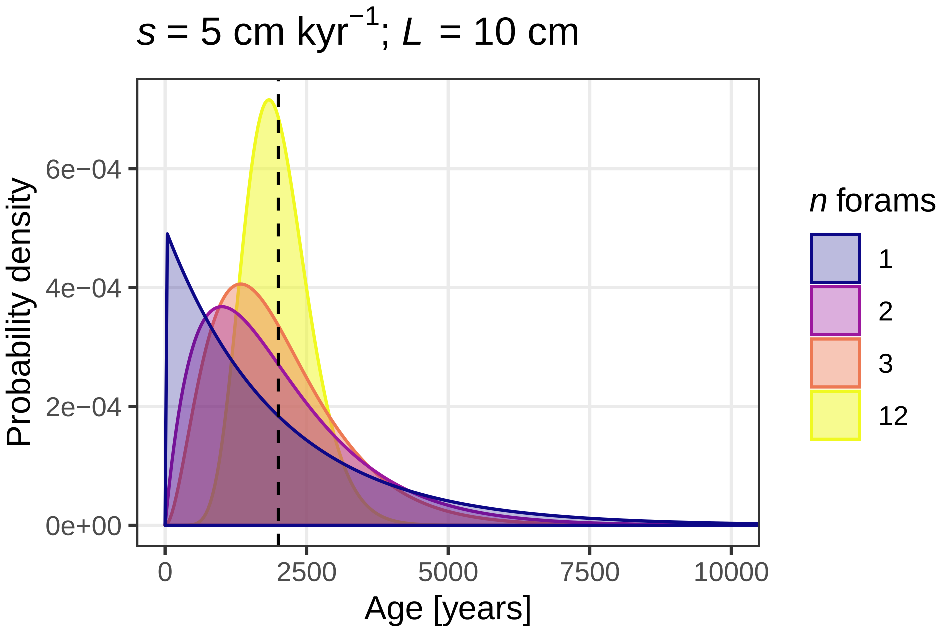

Figure S3. An illustration of the exponential and gamma probability distributions as applied to the age distribution of foraminifera from mixed sediment. Under a simple model of sediment mixing, the age distribution particles is an exponential distribution with standard deviation equal to L/s, where L is the bioturbation depth and s is the sedimentation rate (blue shaded area). When means of samples of n values are taken from an exponential distribution, these means are gamma distributed, with shape parameter $= n$. As n increases, the gamma distribution rapidly approximates a symmetrical distribution. Here the standard deviation (scale) of the exponential is set to 2000 years, the theoretical value for a sediment core with a bioturbation depth L of 10 cm and sedimentation rate s of 5 cm kyr^{-}1. The mean age (dashed vertical line) remains constant as n increases, but the standard deviation shrinks with $\sqrt{n}$.